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26th WRMISS
Workshop on Radiation Monitoring on International Space Station
5 – 7 September 2023

Agenzia Spaziale Italiana

Advancing Space Radiobiology through interdisciplinary research: Insights from the INFN Roma Sapienza AMS Group

Alessandro Bartoloni
On behalf of the AMS Roma Sapienza group
Italian Institute for Nuclear Physics (INFN)

I gratefully acknowledge the strong support from the AMS collaboration, from the INFN Scientific Committee CNS2 and from the Italian Space Agency (ASI) within the agreement ASI-INFN n. 2019-19-HH.0

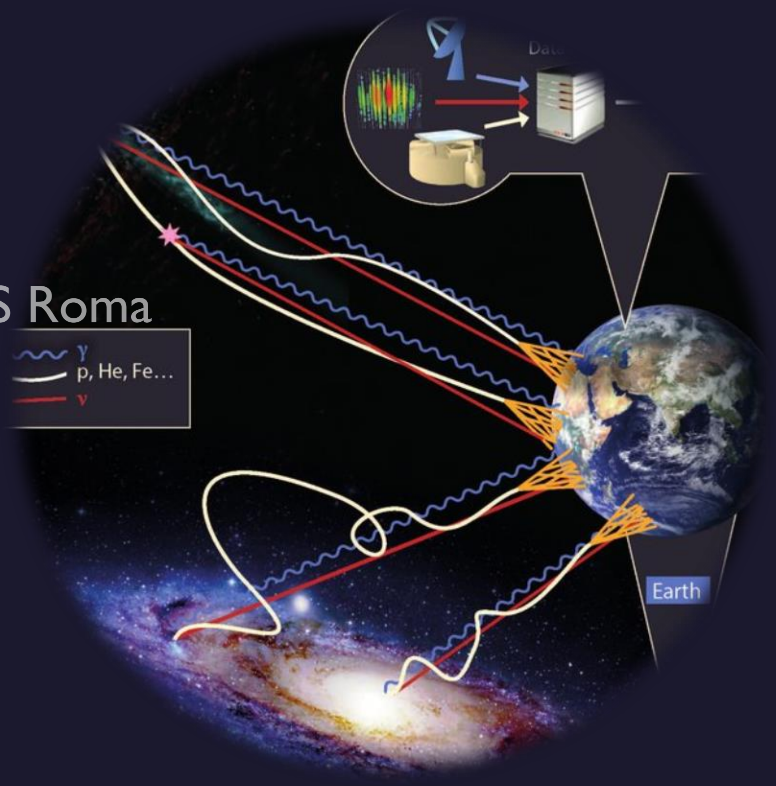
Outline & Keywords

- «Space Radiation-Induced Bystander Effect in Estimating the Carcinogenic Risk Due to Galactic Cosmic Rays" A.N. Guracho
- The AMS Roma Sapienza Group
- Interdisciplinary Enabling Research@AMS Roma Group

Backup slides :

- Space Radiation Characterization
- AstroParticle Experiments

AMS02
(Space Cosmic Ray Detectors)



Space Radiation & Radiobiology

Human Space Exploration

Space Radiation-Induced Bystander Effect in Estimating the Carcinogenic Risk Due to Galactic Cosmic Rays

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We gratefully acknowledge the strong support from the AMS collaboration and from the Italian Space Agency (ASI) within the agreement ASI-INFN n. 2019-19-HH.0.

Space radiobiology is an interdisciplinary science that examines the biological effects of ionizing radiation on humans involved in aerospace missions. The knowledge of the risk assessment of the health hazard related to human space exploration is crucial to reducing damages induced to astronauts from Galactic Cosmic Rays (GCRs) and sun-generated radiation. GCRs have been identified as one of the primary sources of radiation exposure in space.

In this context, an accurate characterization of the possible risk of carcinogenesis induced by exposure to GCRs particles is mandatory for safe human space exploration, and one of the most crucial open problems is the contribution to carcinogenesis due to the effects on the cells directly and not directly irradiated, indicated as Target Effects (TEs) and Non-Target Effects (NTEs), respectively. It is accepted that the detrimental effects of ionizing radiation are not restricted only to the irradiated cells but also to nonirradiated distant cells manifesting various biological effects. Tumour Prevalence (TP) is often used to investigate the effects of NTEs in predictions of chronic GCR exposure risk.

This paper reports the status of the research on this topic at the INFN Roma Sapienza Alpha Magnetic Spectrometer (AMS) research group, where is in progress an extensive study about the risk evaluation of the NTEs that the GCRs radiation will imply when added to the TE. A theoretical framework is presented for TP-induced NTEs modeling, ready to be used with the data collected from the AMS02 detector.

Finally, a possible example of the use of the tool is shown for an accurate estimate of the tumor prevalence function of the exposure period for different typical space protons energies.

Keywords: Human Space exploration, Space Radiation, Space Radiobiology, Radiation Dose-Effects Model, Cancer Risk, Radiation Bystander Effects, Astroparticle Experiments.

Outline

- Material and Methodology
- Cell Survival Probability Models development
- Targeted vs Non-targeted Effects
- The results and An example

graphics summary of the paper

Hazard Function for Gamma ray (H_{γ})

Hazard Function for Charged Particle (H_{CP})

AMS data

Tumor Prevalence for Targeted and Non-targeted Effects (TP_{TE} & TP_{NTE})

Using Alpen et. al. 1993 paper

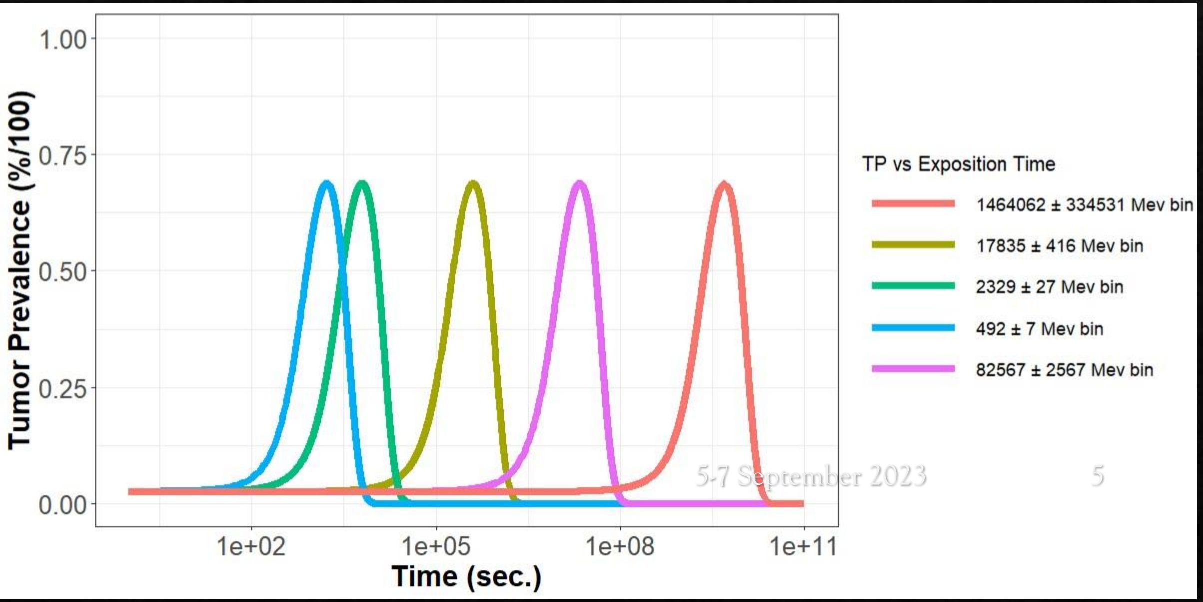
nTNH

LQ Model

... S-SR Model

Cells Survival Probability models (CSP)

Tumor Prevalence in terms of protons flux and exposition time has been calculated using H functions and plotted for protons for data taken from AMS-02 for different bin energy ranges from 492.4±7 MeV to 1.46±0.335 TeV (from 0.24 KeV/μm2 to 0.04 KeV/μm2 LET values)



Materials & Methods: Hazard Function for Tumor Prevalence (TP)

Prevalence is the number of people/cell with a specific disease or condition in a given population at a specific time. This measure includes both newly diagnosed and pre-existing cases of the disease.

Tumor prevalence (TP) is described by a Hazard function, H, which is dependent on radiation type for γ-rays while for charged particles is dependent on the charge number (Z), kinetic energy (E) and fluence (F).

$$TP = 1 - e^{-H(Z,E,F)}$$

$$H_\gamma = H_0 + \left[\alpha_\gamma D + \beta_\gamma D^2\right] * S(D)$$

$$H_{CP}(Z,E,F) = H_0 + \left[\Sigma F + \beta D^2\right] * S(D)$$

Where:

- H_0 represents the background prevalence
- α_γ and β_γ are the linear and quadratic coefficient with dose Induction terms
- Σ is pseudo-biological action cross section taking in account the particle track structure models
- ***S(D)*** is the ***Cell Survival Probability.***

Results: R-script Library includes the most used Cells Survival Probability models

To be used in the calculation of hazard functions of Tumor Prevalence.

1. Theory n-target N-hit model (nTNH)
   Two special cases of nTNH including:
   - Theory single Target single hit model (sTSH)
   - Theory single Target N-hit model (sTNH)
2. Theory Linear Quadratic Model (LQ)
3. Linear Quadratic Model modified by hyper-radiosensitivity(HRS) effect.
4. Theory Linear Quadratic Cubic Model (LQC) for high dose.
5. Sublesion Theory Repair – misRepair Model (S-RMR)
6. Sublesion Theory Lethal – potentially lethal Model (S-LPL)
7. Sublesion Theory Saturable Repair Model (S-SR)

1. $S(D) = 1 - (1 - B)^n,\ B = e^{\frac{-D}{D_0}}[1 + \sum_2^N \frac{\left({}^{D}/{}_{D_0}\right)^{N-1}}{(N-1)!}]$

2. $S(D) = e^{-\alpha D - \beta D^2}$

3. $S(D) = exp\{-\alpha\left(1 + \left(\frac{\alpha_s}{\alpha} - 1\right) e^{\frac{-D}{D_0}}\right) D - \beta D^2\}$

4. $S(D) = e^{-\alpha D - \beta D^2 - \gamma D^3}$

5. $S(D) = e^{-aD}[1 + (\frac{aD(1-e^{(-\lambda T)})}{\varepsilon})]^{\varepsilon\phi}$

6. $S(D) = e^{-(n_L - n_{PL})D}[1 + \frac{n_{PL}D}{\epsilon}(1 - e^{-\epsilon_{PL} t_r})]^{\epsilon}$

7. $S(D) = e^{-\frac{n_0 - C_0}{1 - \frac{C_0}{n_0} e^{kT(C_0 - n_0)}}}$

Hazard Function
Targe Effect (TE) vs Non-Target Effects (NTE)

The hazard function in the TE and TE + NTE case for charged particles:

The η function represents the NTE contribution, which is parameterized as a function of the particle Linear Energy Transfer (L).

We tuned the radiobiological parameters to reproduce available experimental data

$$H_{TE}(Z,E,F) = H_0 + [\,\Sigma F + \beta D^2] * S$$

$$H_{NTE}(Z,E,F) = H_0 + [\,\Sigma F + \beta D^2 + \eta] * S$$

$$\eta = \eta_0 L e^{-\eta_1 L}[1 - e^{-N_{Bys}}]$$

Where:

- L is the Linear Energy Transfer of the particle
- N_{Bys} is the number of bystander
- $N_{Bys} = \text{Fluence} * A_{Bys}$
- A_{Bys} is an area corresponding to the number of bystander cells surrounding a cell traversed directly from a HZE particle that receive an oncogenic signal.

Experimental Data Set (Alpen et. al. 1993)

Prevalence of Harderian Gland Tumors

- Gammas 55.5TBq Co60
- Hydrogen with energy 250A, LET 0.4 KeV/µm
- Exposition time between 60 sec. to 120 sec.
- Irradiation field is 3 x 5 cm^2.
- Background Prevalence is $H_0 = 0.026$

Table III

Prevalence of Harderian Gland Tumors after Irradiation with Proton ions

Mice				
Dose (Gy)	Number	At risk	With tumors	Prevalence[a]
0	198	155	4	2.6 ± 2.5
0.4	47	44	43	9.3 ± 6.1
0.8	42	41	8	19.5 ± 12.1
1.6	48	43	13	30.2 ± 13.7
3.2	28	24	7	29.2 ± 18.2

[a] ±95% CI

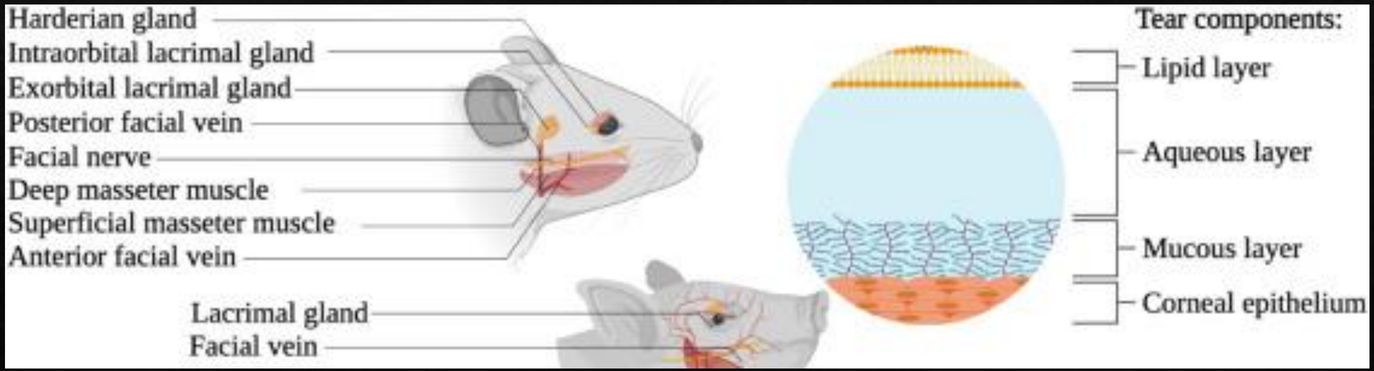
Table II

Prevalence of Harderian Gland Tumors

After 60Co Gamma Irradiation

Mice				
Dose (Gy)	Number	At risk	With tumors	Prevalence[a] (%)
0	198	155	4	2.6 ± 2.5
0.4	292	229	11	4.8 ± 2.7
0.8	278	161	15	9.3 ± 4.5
1.6	244	117	16	13.7 ± 6.2
3.2	181	115	37	32.2 ± 8.5
7.0	90	52	24	46.2 ± 13.6

[a] ±95% CI

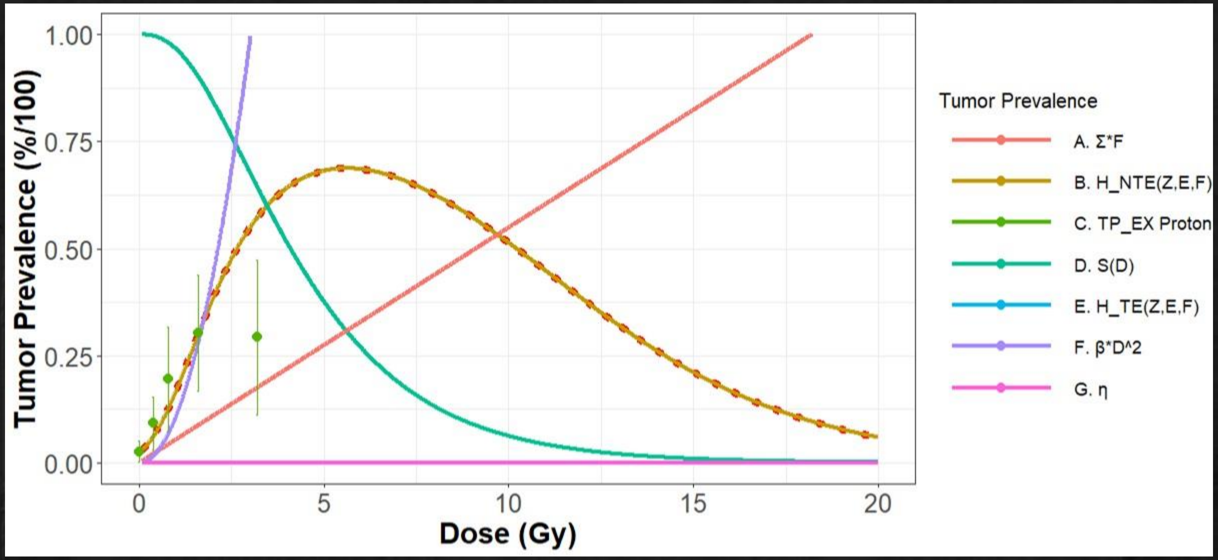


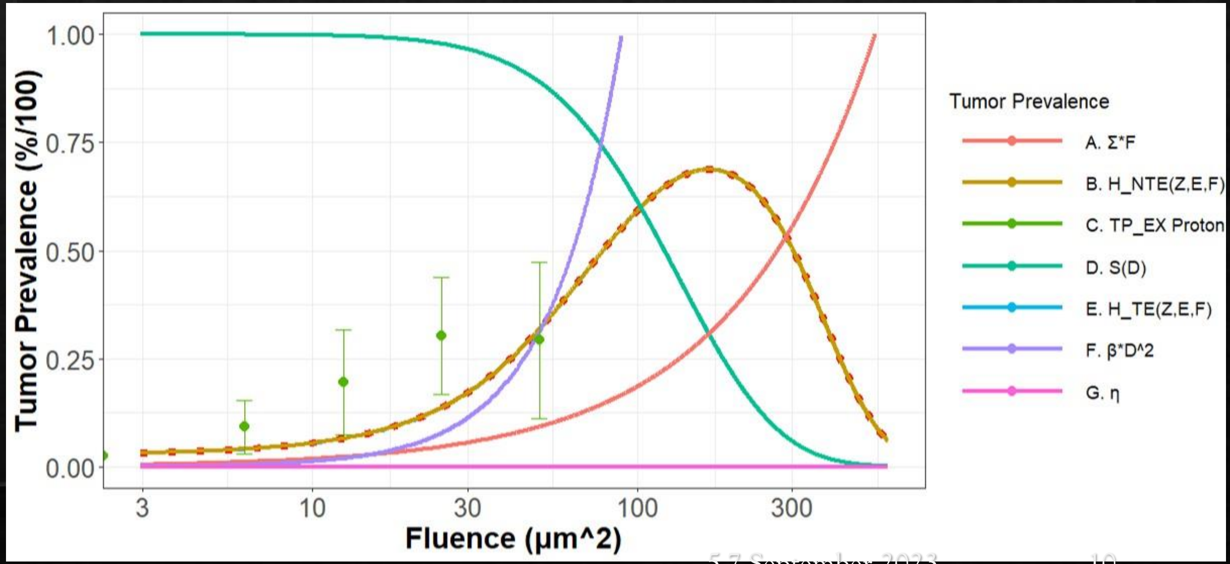
Results: TE vs TE+NTE Models for protons

In the figures, all the components of the H functions are shown separately for the TE and TE+NTE models respectively.

Calculation of the TE and NTE TP models showing for Proton 250A MeV there are no relevant differences in the tumor Prevalence versus dose as expected (NTE models predict the same tumor prevalence at low doses compared to the TE model).

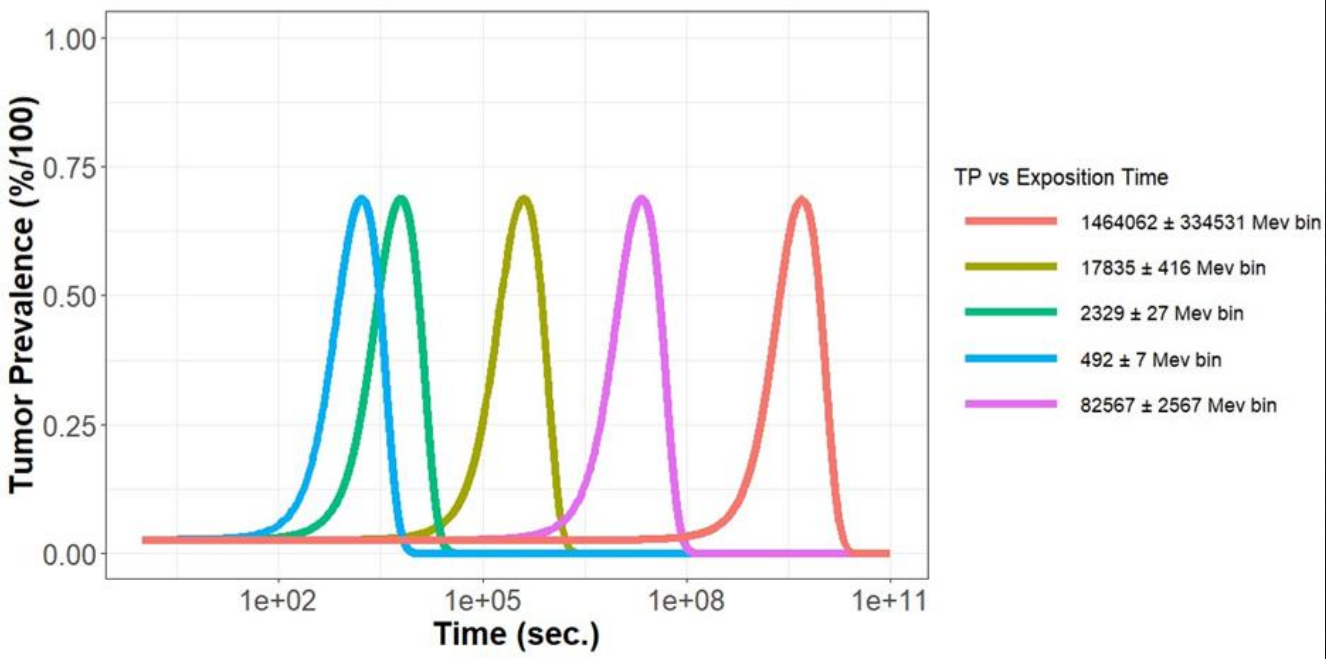
The shape of the tumor response curve found in the NTE model is a shallow non-linear dose-response curve.





An Example: AMS-02 protons

Tumor Prevalence in terms of protons flux and exposition time has been calculated using H functions and plot for protons for data taken from AMS-02 for different bin energy ranges from 492.4±7 MeV to 1.46±0.335 TeV (from 0.24 KeV/μm^2 to 0.04 KeV/μm^2 LET values)



Journal of Mechanics in Medicine and Biology
“SPACE RADIATION INDUCED BYSTANDER EFFECT IN ESTIMATING THE CARCINOGENIC RISK DUE TO GALACTIC COSMIC RAYS” A. Guracho et al (published in May 2023)

Summary

We developed an-ad hoc software in R-script language for Tumor Prevalence risk calculation including the more reliable dose-effect models for space radiation.

An r-script library with different Cell Survival Probability models was developed to be used in the calculation of hazard functions of Tumor Prevalence.

Using the software and the experimental data set of the Harderian Gland Tumor, we tune all the parameters for the Tumor Prevalence Model for protons and show no substantial differences between the Target and Non-Target Effects as expected.

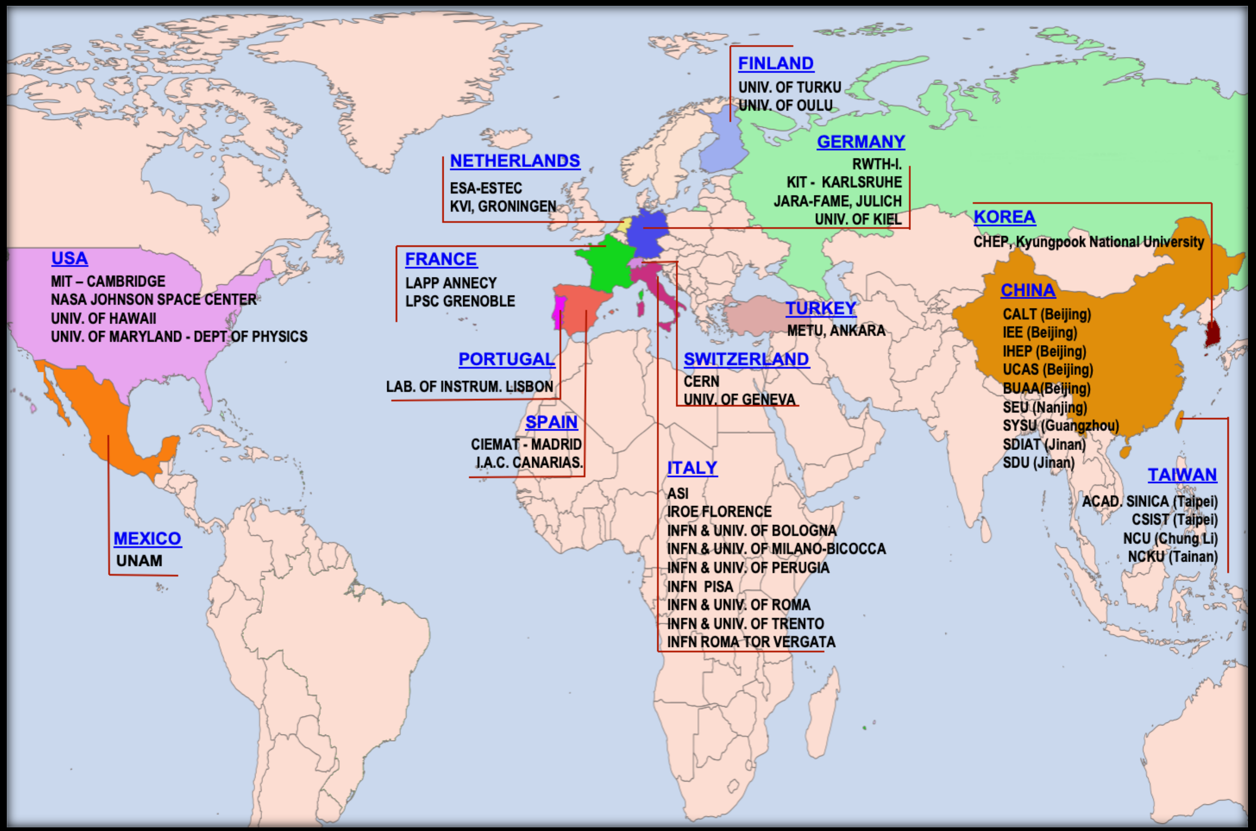
We apply the model for protons using the cosmic ray protons component as measured and published by the AMS detector as an example.

In the future, we extend the analysis to heavy ions, and we will use the data collected from the AMS02 detector to increase the modelling accuracy and risk prediction.

The AMS Roma Sapienza Research Group

Alpha Magnetic Spectrometer AMS02

AMS is a particle detector measuring Galactic Cosmic Ray fluxes.
It was installed on the International Space Station (ISS) on May 19, 2011



The AMS collaboration

(http://ams02.space)

An international collaboration made of 44 Institutes from America, Asia and Europe

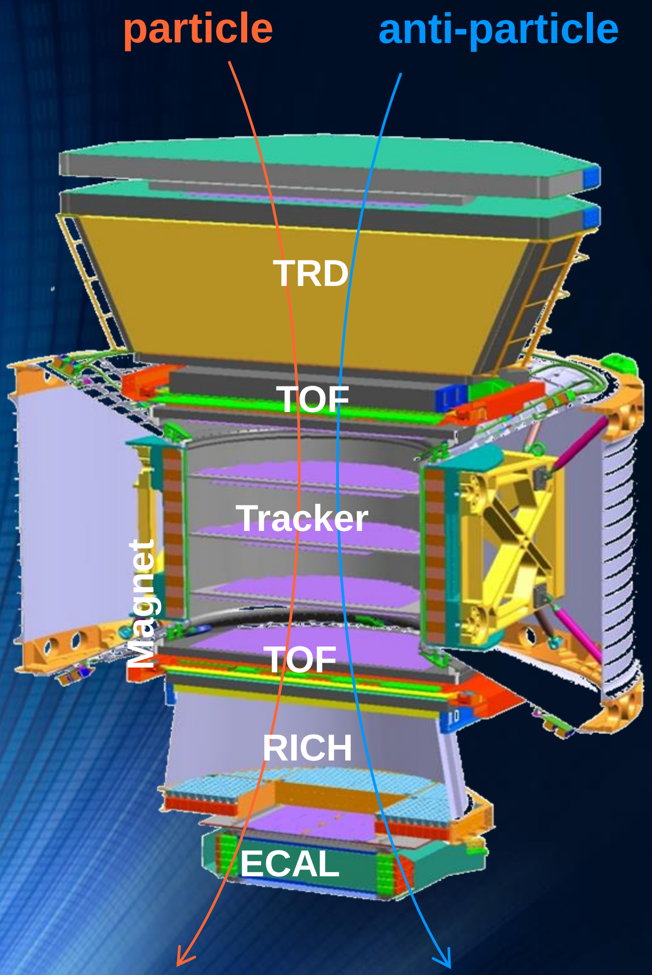
It uses the unique environment of space to study the universe and its origin by searching for antimatter, dark matter while performing precision measurements of cosmic rays' composition and flux.

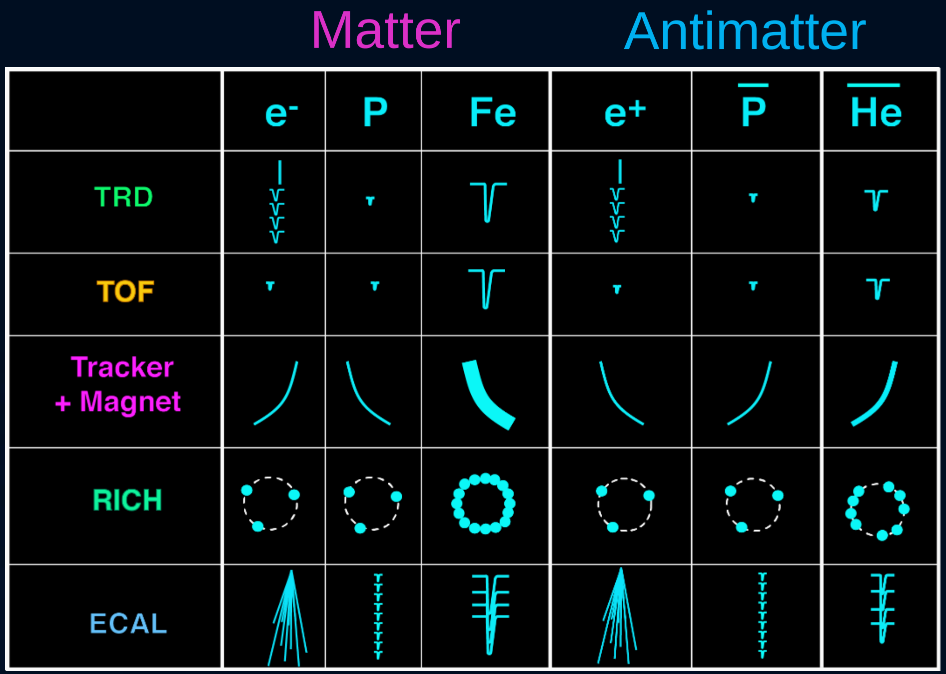
The AMS Payload Operation Control Center at CERN operates 365 days year h24

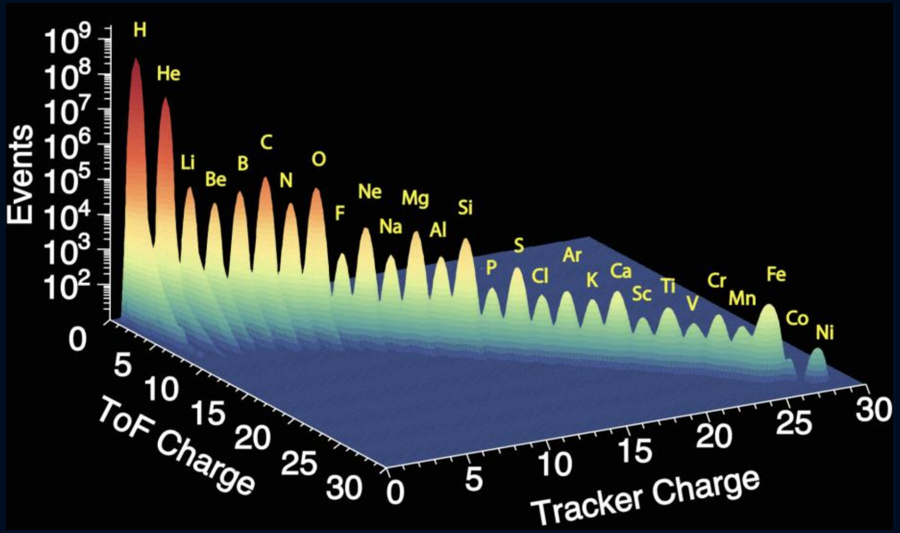
The AMS02 detector has collected so far more than **250 billion** Cosmic Rays events.

More Info in the AMS-02 webpage:
https://ams02.space

AMS is a space version of a precision detector used at accelerators





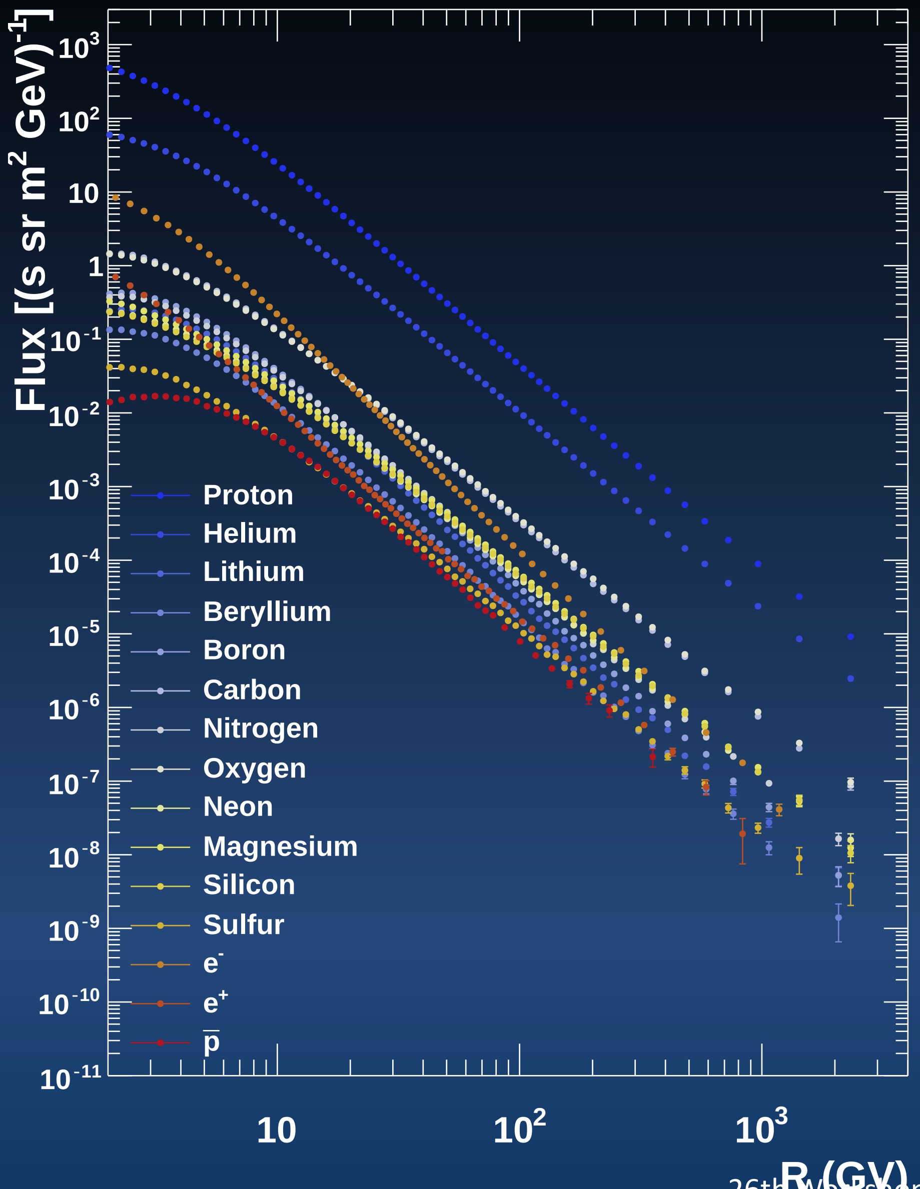


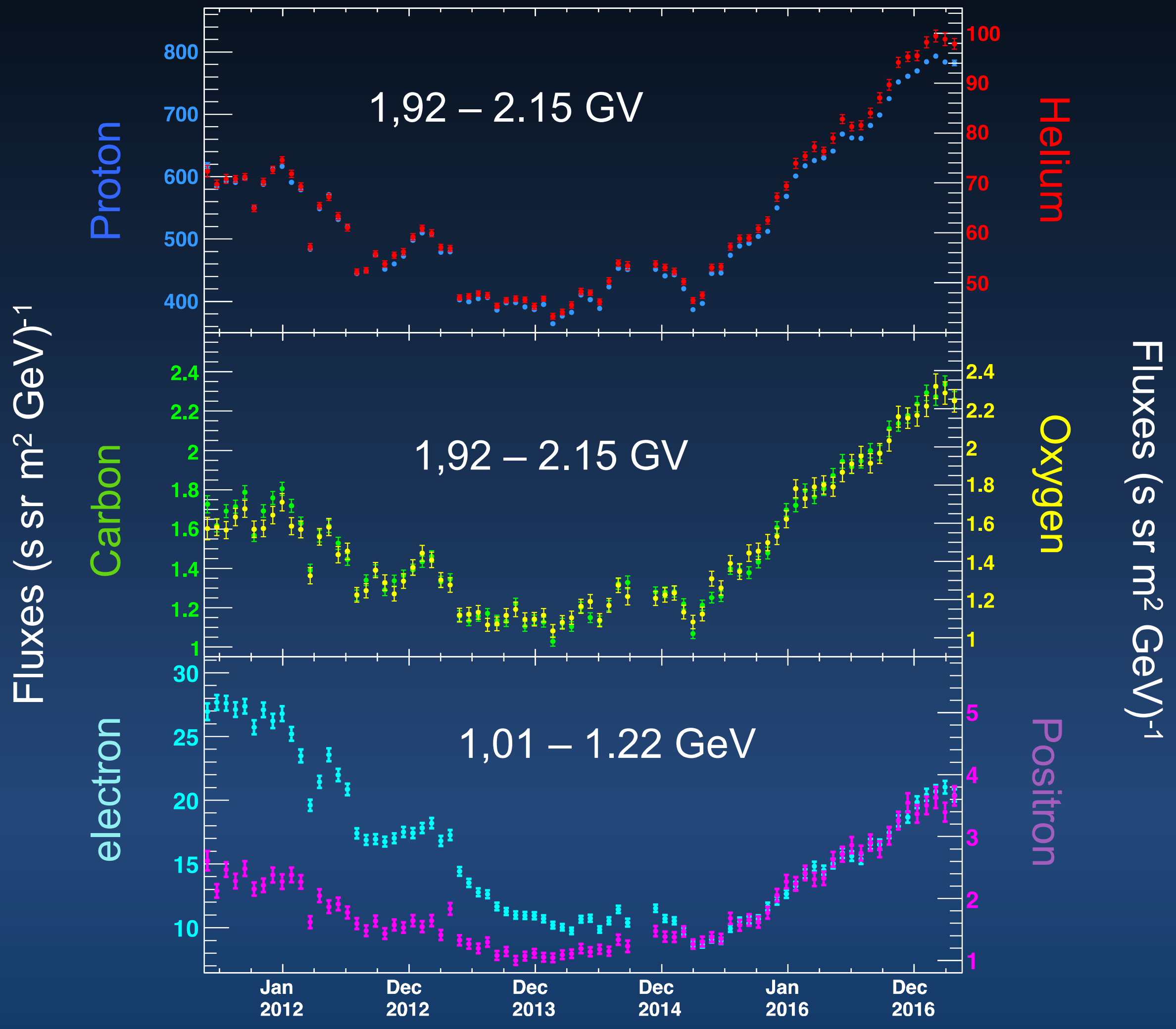
Cosmic-ray properties

Dark Matter searches

Primordial antimatter searches

AMS – Measurements





Particle	Ref.	Rigidity Range (GV), [bins]	Measurement Type	Time Period	Number of Events
Electron (e^+, e^-)	[46]	1.0 – 350 [19]	Absolute Flux	2011/2012	Over $6.8x10^6$
Electron (e^++ e^-)	[47]	0.5 – 1000 [74]	Absolute Flux	2011/2013	$10.1x10^6$
Electron (e^+ + e^-)	[48]	0.5 – 1400 [75]	Absolute Flux	2011/2017	$28.1x10^6$
Proton (p^+ + p^-)	[51]	1 – 1800 [72]	Absolute Flux	2011/2013	$3.8 x 10^8$
Proton (p^+ + p^-)	[58]	1 – 450 [57]	Absolute Flux	2011/2015	$2.8 x10^9$
Helium (He)	[55]	1.92 – 3000 [68]	Absolute Flux	2011/2013	$50x10^6$
Helium (He)	[52]	1.92 – 3000 [68]	Absolute Flux	2011/2016	$90x10^6$
Lithium (Li)	[57]	1.92 – 3300 [67]	Absolute Flux	2011/2016	$1.9x10^6$
Beryllium (Be)	[57]	1.92 – 3300 [67]	Absolute Flux	2011/2016	$0.9x10^6$
Boron (B)	[57]	1.92 – 2600 [67]	Absolute Flux	2011/2016	$2.6x10^6$
Boron (B)	[64]	2.15 – 3300 [66]	Absolute Flux	2011/2021	$1.8 x 10^{11}$*
Carbon (C)	[58]	1.92 – 3000 [68]	Absolute Flux	2011/2016	$8.4x10^6$
Carbon (C)	[64]	2.15 – 3000 [48]	Absolute Flux	2011/2021	$1.8 x 10^{11}$*
Nitrogen (N)	[59]	2.15 – 3300 [66]	Absolute Flux	2011/2016	$2.2x10^6$
Oxygen(O)	[58]	2.15 – 3000 [67]	Absolute Flux	2011/2016	$7.0x10^6$
Oxygen(O)	[64]	2.15 – 3000 [48]	Absolute Flux	2011/2021	$1.8 x 10^{11}$*
Oxygen(O)	[64]	2.15 – 3300 [66]	Absolute Flux	2011/2021	$1.8 x 10^{11}$*
Fluorine (F)	[62]	2.15 – 2900 [48]	Absolute Flux	2011/2019	$0.29x10^6$
Fluorine (F)	[64]	2.15 – 3000 [48]	Absolute Flux	2011/2021	$1.8 x 10^{11}$*
Neon (Ne)	[60]	2.15 – 3000 [66]	Absolute Flux	2011/2018	$1.8x10^6$
Neon (Ne)	[64]	2.15 – 3000 [48]	Absolute Flux	2011/2021	$1.8 x 10^{11}$*
Sodium (Na)	[61]	2.15 – 3000 [48]	Absolute Flux	2011/2019	$0.46x10^6$
Magnesium (Mg)	[60]	2.15 – 3000 [66]	Absolute Flux	2011/2018	$2.2x10^6$
Magnesium (Mg)	[64]	2.15 – 3000 [48]	Absolute Flux	2011/2021	$1.8 x 10^{11}$*
Silicon (Si)	[60]	2.15 – 3000 [66]	Absolute Flux	2011/2018	$1.6x10^6$
Silicon (Si)	[64]	2.15 – 3000 [48]	Absolute Flux	2011/2021	$1.8 x 10^{11}$*
Sulfur (S)	[64]	2.15 – 3000 [48]	Absolute Flux	2011/2021	$0.38×10^6$
Iron (Fe)	[63]	2.65 – 3000 [46]	Absolute Flux	2011/2019	$0.62x10^6$

Properties of Cosmic-Ray Sulfur and Determination of the Composition of Primary Cosmic-Ray Carbon, Neon, Magnesium, and Sulfur: Ten-Year Results from the Alpha Magnetic Spectrometer

(PHYSICAL REVIEW LETTERS 130, 211002 (2023))

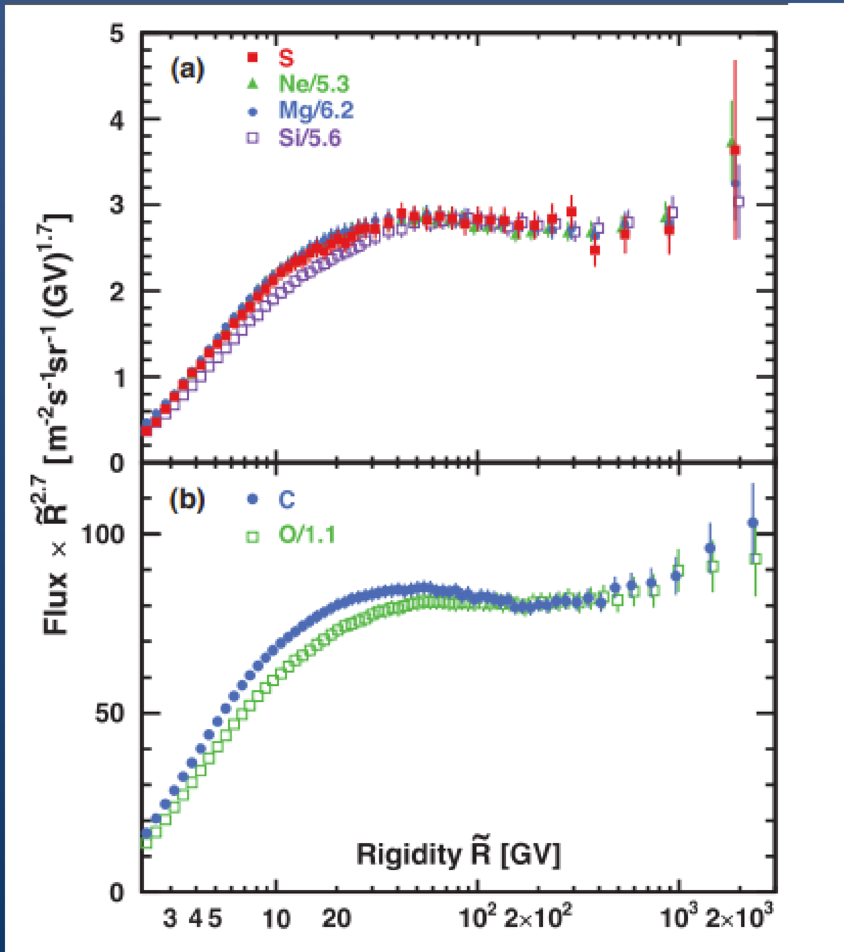


FIG. 1. (a) The AMS S flux multiplied by $\tilde{R}^{2.7}$ with total errors as a function of rigidity together with the AMS Ne, Mg, and Si fluxes. As seen, rigidity dependences of S, Ne, and Mg fluxes are very similar, and are different from Si flux at low rigidities. The rigidity dependences of all four fluxes are identical at high rigidities. (b) The AMS C and O fluxes multiplied by $\tilde{R}^{2.7}$ with total errors as functions of rigidity. As seen, rigidity dependences of C and O fluxes are identical at high rigidities, but also different at low rigidities. For clarity, the Ne, Si, and O data points above 50 GV are displaced horizontally, and, for display purposes only, Ne, Mg, Si, and O fluxes were rescaled as indicated.

Particle	Ref.	Rigidity Range (GV), [bins]	Measurement Type	Time Period	Number of Events
Electron (e+ + e-)	[49]	1 - 41.9 [10]	Time Variation (4015-d)	2011/2021	$2.0x10^8$
Electron ($e^+ + e^-$)	[50]	0.5 – 49.33 [52]	Time Variation (79-b)	2011/2017	$23.5x10^6$
Proton ($p^+ + p^-$)	[53]	1 – 100 [30]	Time Variation (114-b)	2011/2019	$5.5 x10^9$
Helium (He)	[54]	1.92 – 60 [40]	Time Variation (79-b)	2011/2017	$112x10^6$
Helium (He)	[56]	1.71 – 100 [26]	Time Variation (2824-d)	2011/2019	$7.6x10^8$

Light Nuclei Fluxes as Function of Time

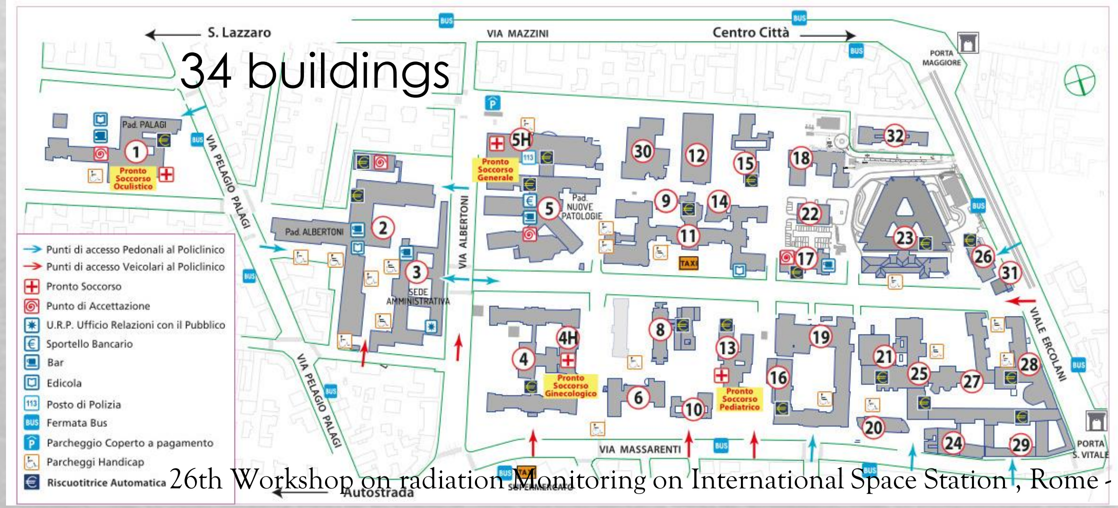
(see Federico Donnini yesterday talk)

Fluxes has been normalized to Lithium flux

The AMS SPRB collaboration was created in 2017 by the synergy of the AMS INFN Roma Sapienza (Italy) group leaded by Alessandro Bartoloni with the medical physics research group leaded by Lidia Strigari currently at IRCCS university Hospital of Bologna (Italy)

IRCCS Azienda Ospedaliero-Universitaria di Bologna
Department of Medical Physics
Bologna, Italy

- 4 linacs (Electrons & Gamma Ray)
- 1 Brachytherapy High Dose Rate system (^{192}Ir)
- 1 Roentgen-therapy
- 1 ^{137}Cs Irradiator
- 1 CT for RT planning



34 buildings

3 Versa HD
(6MV, 6FFF, 10MV, 10FFF, 15MV)

Siemens
(6MV ,18MV)

Microselectron HDR ^{192}Ir
A=500 GBq

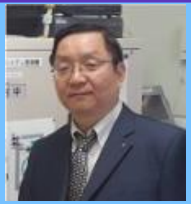
^{137}Cs Irradiator
A=36.67 TBq

RX THERAPAX 300
(300kV)

IRCCS Azienda Ospedaliero-Universitaria di Bologna
Department of Medical Physics
Bologna, Italy

- 4 linacs

- **4 PET/CT**
- **4 SPECT/CT**
- **1 department (8 beds) for molecular radiotherapy**



Feng
Ru Tang
National University of Singapore

Aurelian
Marcu
National Institute for Laser, Plasma and Radiation Physics - Romania

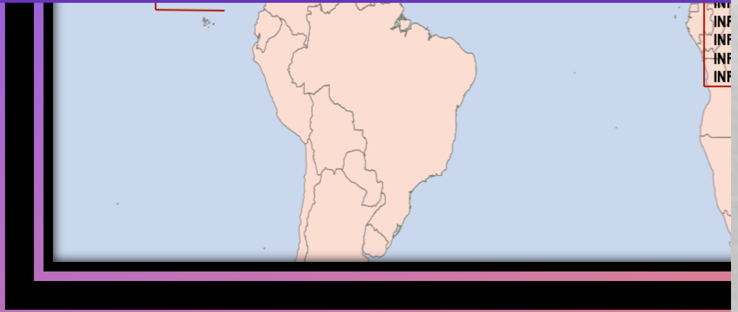
Sara
Parsaei

Mustafa
Rafiei

Shahid Bahonar University of Kerman

Faith
Tng
Space Generation Advisory Council

Emilio
Perez De Juan



Marco
Peroni
Peroni Ingegneria

Maurizio
Repetto
Politecnico di Torino

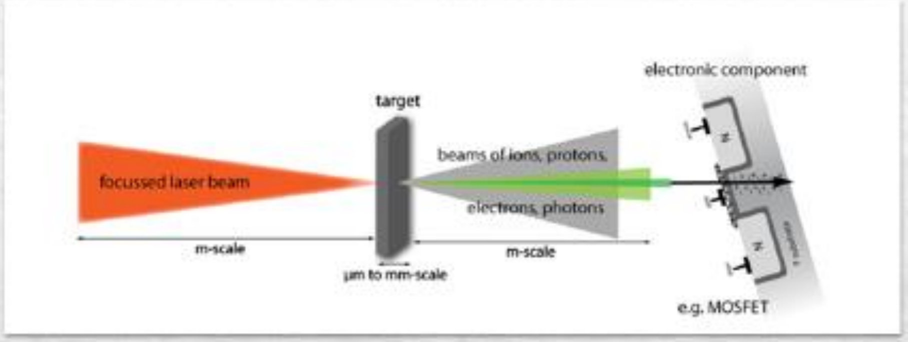
Laser–Plasma-Accelerators—A novel,versatile tool for space radiation studies

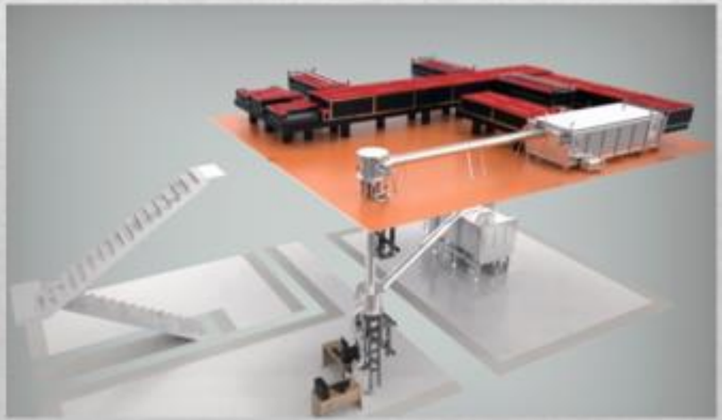
Testing radiobiological samples in space missions are among the most expensive and time-consuming processes in life space science study.

LPAs could substantially decrease the costs and time consumption of these tests to benefit all the national space agencies and international collaborations involved in space mission design.

Consequently, their use could reduce the mission's design times and improve overall safety thanks to the deep comprehension of mechanistic radiobiological models.

Thus, testing by LPAs could enhance the knowledge of the health risk of future space missions beyond the current progress. Furthermore, using LPA instead of radioactive radiation sources or poly-energetic accelerators is also desirable under proliferation and management aspects.





2ND AMS/SPRB INTERCHANGE MEETING
(BOLOGNA 18-20 JULY 2023)

Collaborations were mainly focused on creating synergy within different scientific communities

(radiobiology, medical physics, radiotherapy, and nuclear medicine)

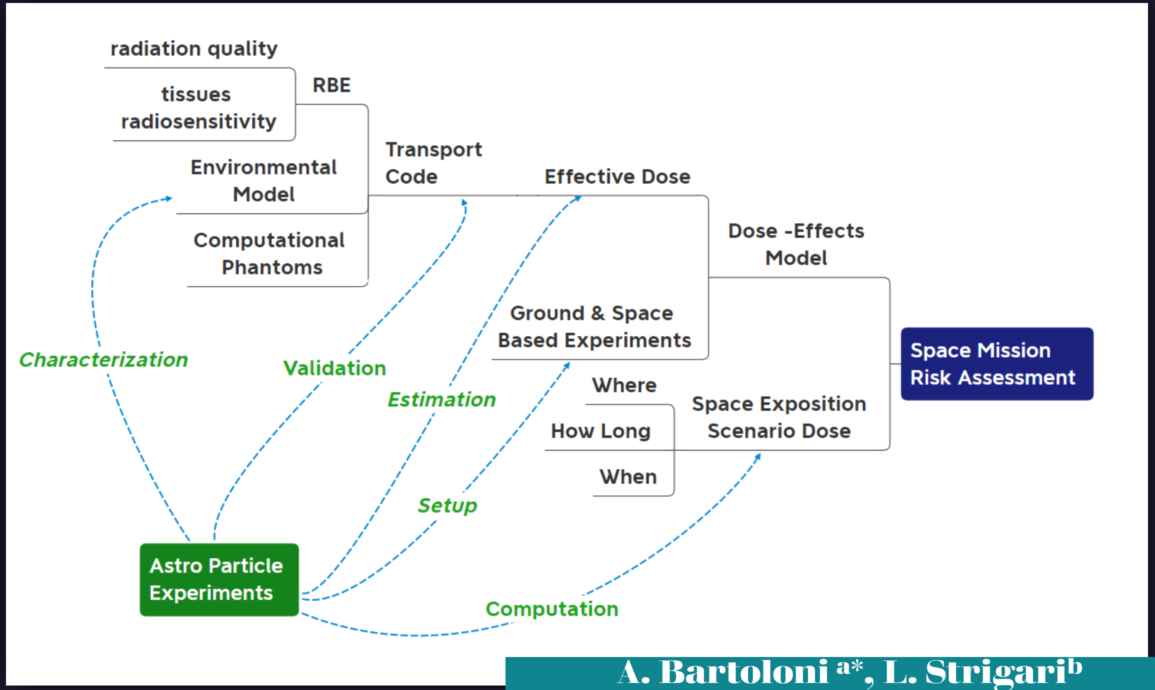
and Institutions playing a crucial role in the human space exploration

(Research, Universities, and National Space Agencies).

We have many studies on the capabilities and possibilities in that direction, especially regarding the AMS02 and also we identify many opportunities for improvement.

AMS02 GCR sensitivity analysis

A. Bartoloni [a*], L. Strigari[b]
SIF2019



A. Bartoloni [a*], L. Strigari[b]
GLEX-21-8.2.5 (ID:62186)

I gratefully acknowledge the strong support from the AMS collaboration and from the Italian Space Agency (ASI) within the agreement ASI-INFN n. 2019-19-HH.0.

Agenzia Spaziale Italiana

Astronaut Radiation Dose Calculation With a New Galactic Cosmic Ray Model and the AMS-02 Data

Xuemei C. et. al.

Research Article:
17 April 2023
10.1029/2022SW003285

ADVANCING EARTH AND SPACE SCIENCE

Q(R,E) ICRP$_{60}$

Q(R,E) NASA

Tissue weighting factor (WT)

Equivalent Dose rate ($H_{T,R}$) $\sum_{T} w_T H_{T,R}$ Effective Dose Equivalent rate ($H_{E,R}$) $\sum_{R} H_{E,R}$ Total Effective Dose Equivalent rate (H_E)

AMS data

Local Interstellar Spectra (LIS)

3D &T.M. (GCR model)

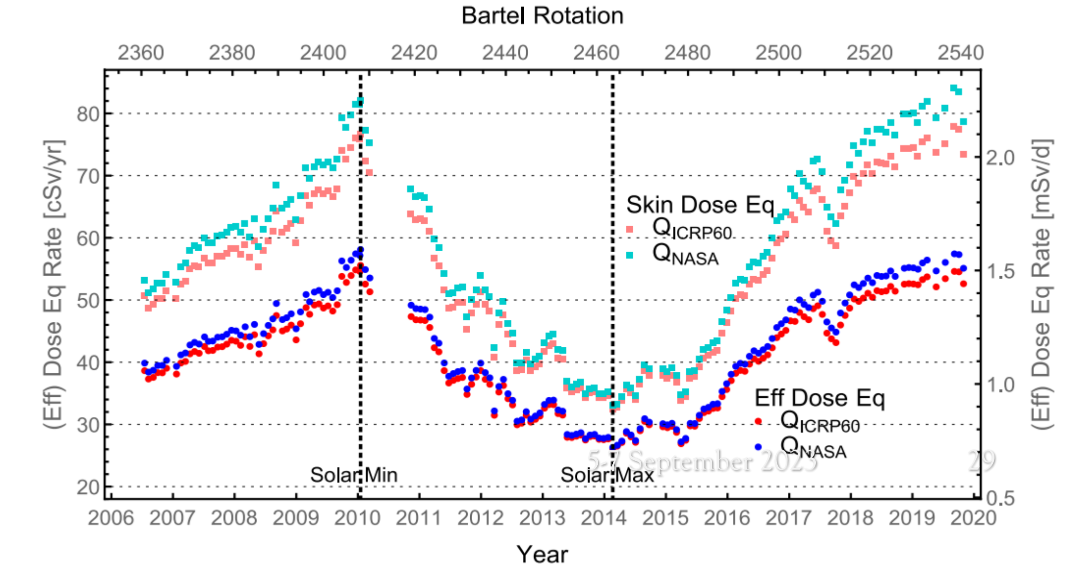
N.E.S.

SPECT(R)

17 /07/ 2006 to 31 /10/ 2019

Bartel Rotation 2360 - 2540

The time series for effective dose equivalent rates and skin dose equivalent rates in the time window (17 July 2006 to 31 October 2019), with genders averaged but two quality factors shown.



Enabling Research @ AMS Roma Group

Dose-Effects Models

We made and publish in 2021 an extensive review of the existent literature to use as starting point for improvements this research areas

Articles dose-effect models search and identification

Identification of	Experimental Type	Study Type
Types of irradiation	In Vitro	Ground
Data	Pre-clinical	Simulation
Models	Clinical	Spaceflight

REVIEW article

Front. Public Health, 08 November 2021
Sec.Radiation and Health
https://doi.org/10.3389/fpubh.2021.733337

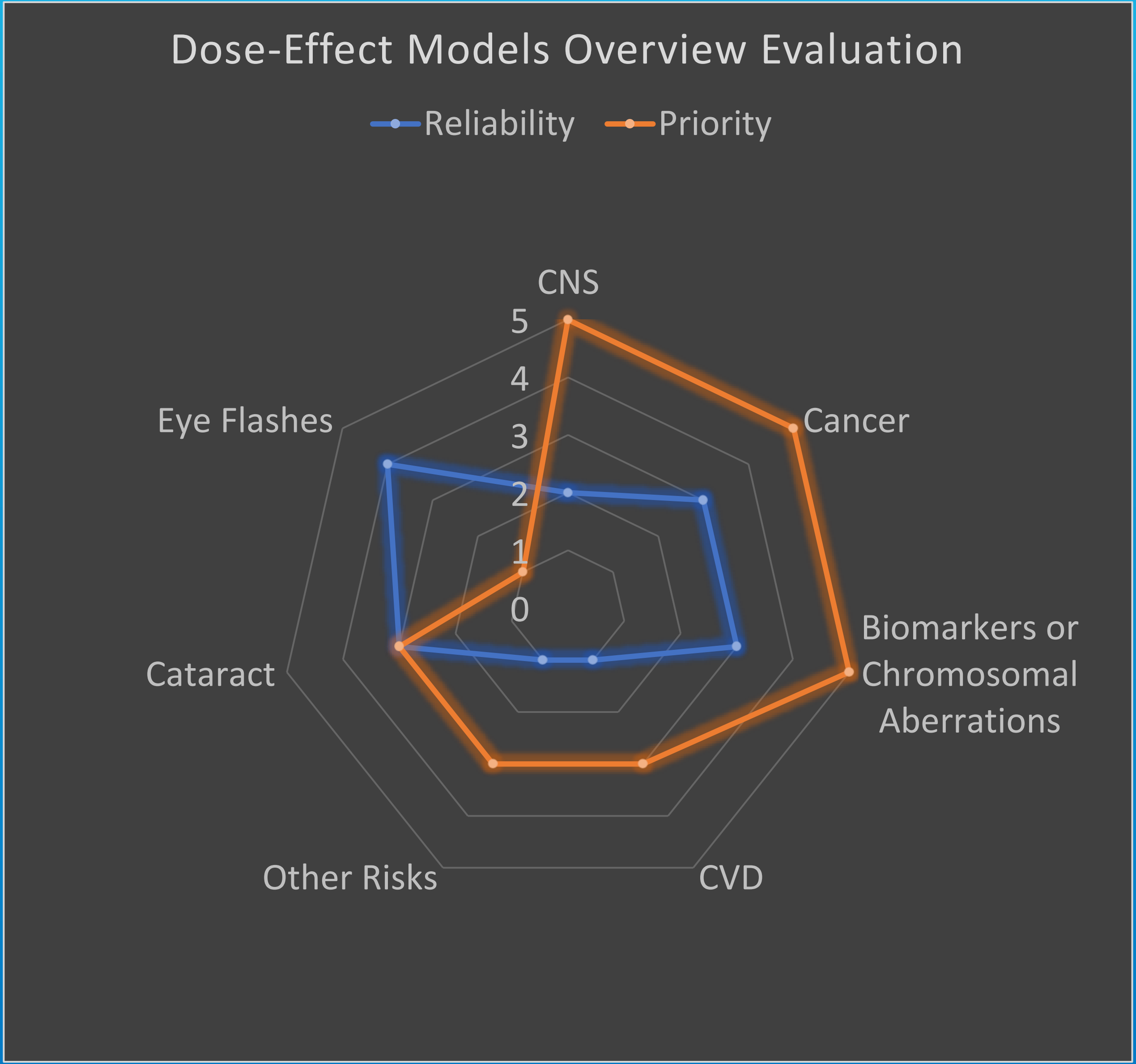
This article is part of the Research Topic
Medical Application and Radiobiology Research of Particle Radiation
View all 16 Articles >

Dose-Effects Models for Space Radiobiology: An Overview on Dose-Effect Relationships

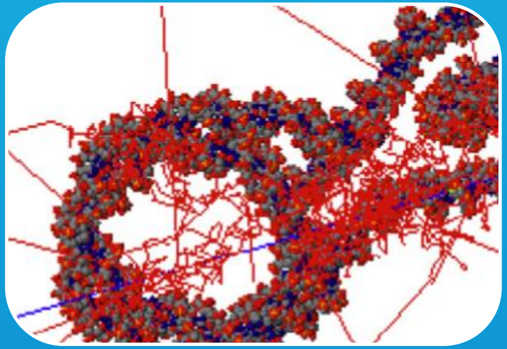
Lidia Strigari[1], Silvia Strolin[1], Alessio Giuseppe Morganti[2] and Alessandro Bartoloni[3*]

https://doi.org/10.3389/fpubh.2021.733337

Model	Study Type	Dose Range/Threshold or LET	#Papers
Eye Flashes	Spaceflight	LET>5-10 KeV/µm	4
Cataract	Spaceflight	8 mSv	5
CNS	Ground/Simulations	100-200 mGy	11
CVD	Spaceflight	1000 mGy	4
	Ground/Simulations	0.1-4,500 mSv	8
Cancer	Spaceflight	< 100 mGy	2
	Ground/Simulations	< 100 mGy	9
Biomarkers or Chromosomal Aberrations	Spaceflight	<5-150 mGy	11
	Ground /Simulations	< 10,000 mGy	4
Other Risks	Ground/Simulations	2,000 mGy	2
= Very Low, **=Low,*=Medium,**** = High, ***** = Very High.*			



Further investigation are required to produce dose-effects models that will allows to predict the risk due to radiation during the space exploration



Computer Simulation of interactions of IR with biological matter

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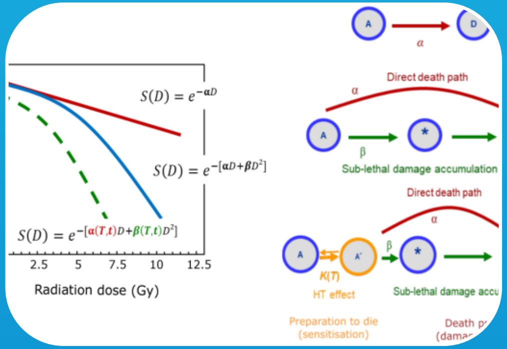
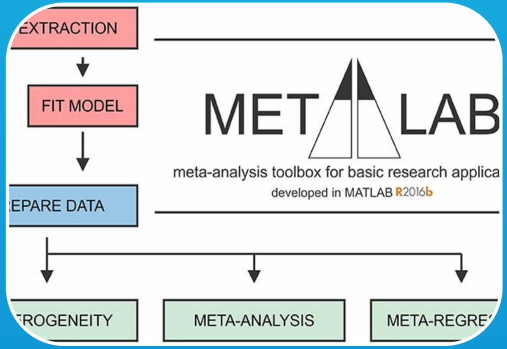
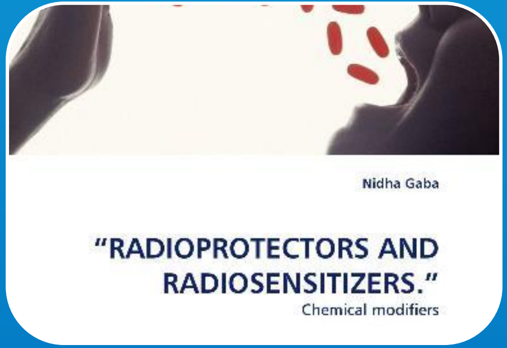
Synergy with the Clinical Field



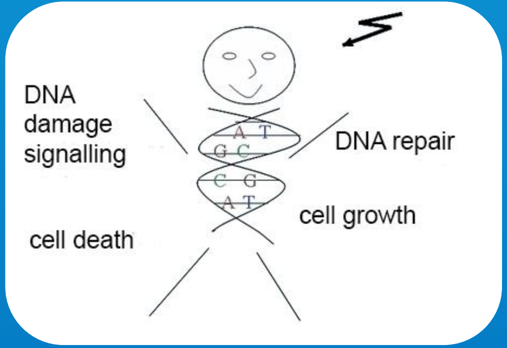
Mathematical Modelling



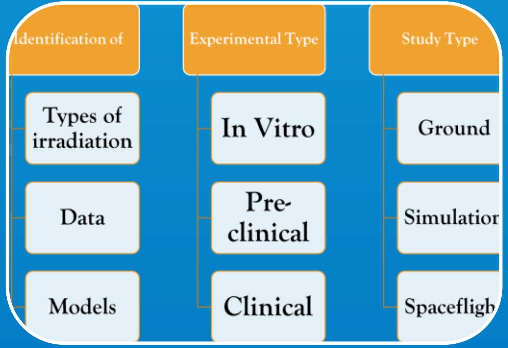
Quantitative Meta Analysis



Radioprotectors inclusion in DER



Individual Radio Susceptibility



Dose-Effects Model Integration Platform

Synergy with Astroparticle Experiments

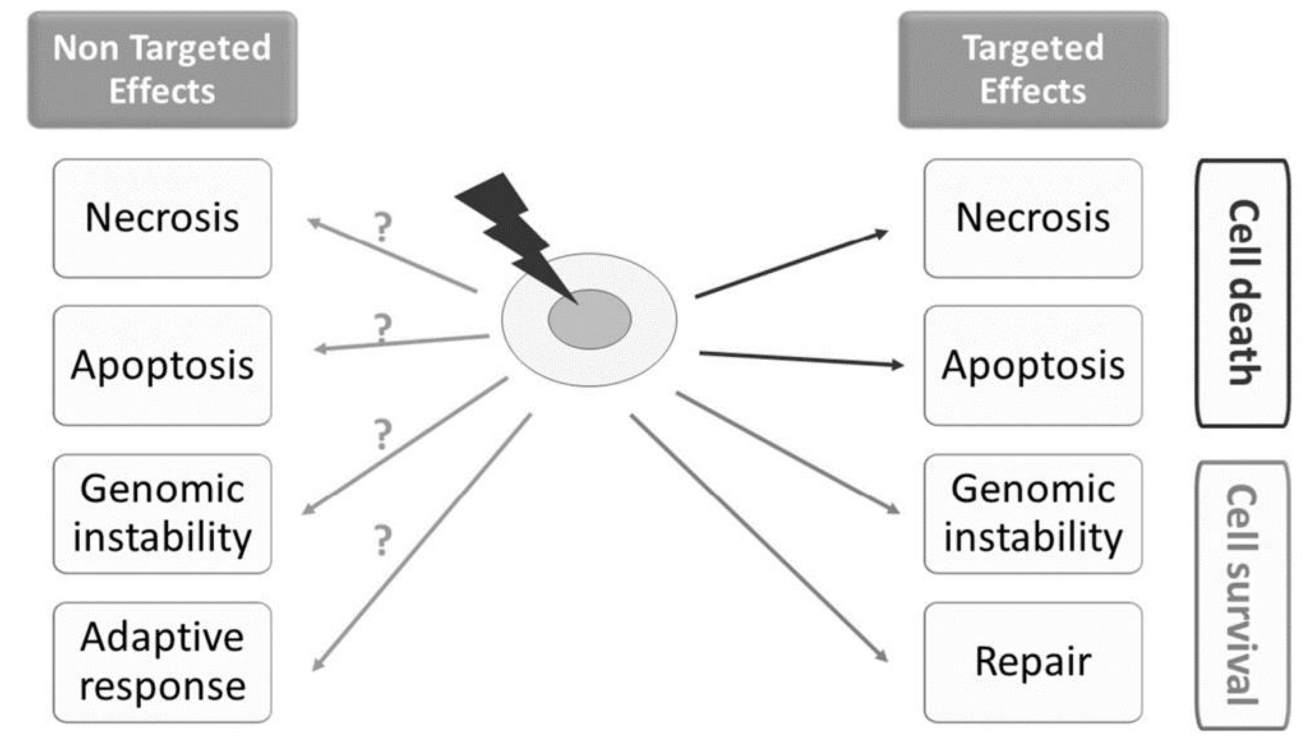
Target Effects vs Non Target Effects

Following this analysis, we started to investigate one of the promising and not yet understood effects of ionization radiation, usually referred to as the non-targeted effect (NTE) of great relevance for space radiation.

In-vitro and in-vivo pre-clinical studies as well as many mechanistic studies support the NTEs, with evidence of a a supra-linear effects at low doses of NTE compared to the linear one of TE

NTEs include bystander effects where cells traversed by heavy ions transmit oncogenic signals to nearby cells and genomic instability in the cell's progeny.

The NTE are expected also at the fluences and space radiation species that occur in space



An example on Research activities on DEM in progress at AMS INFN Roma-Sapienza Group

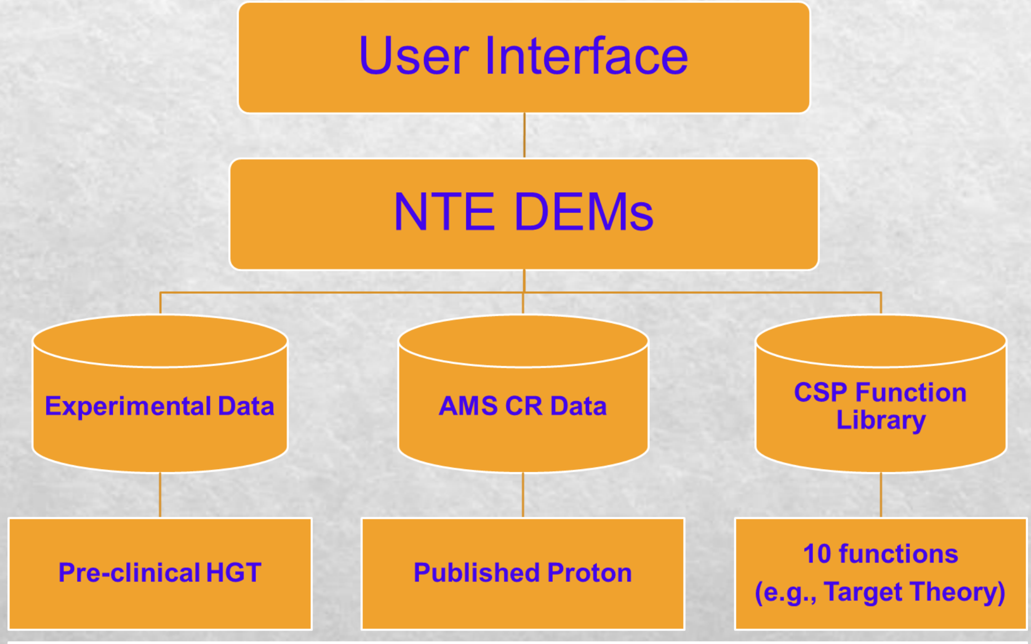


Fig.1 The NTE-DEM v1.0 architecture.

The NTE-DEM aims to combine the existing experimental data (clinical, pre-clinical and in vitro), the cosmic ray fluences, as measured by the AMS detector and the cell survival probability function existing in the literature to produce reliable DEMs.

We use the R-Studio integrated development environment to code it. The first NTE-DEM release (Fig. 1) comprises a main program and several libraries for>10K lines of code.

Journal of Mechanics in Medicine and Biology
"SPACE RADIATION INDUCED BYSTANDER EFFECT IN ESTIMATING THE CARCINOGENIC RISK DUE TO GALACTIC COSMIC RAYS" A. Guracho et al (published in May 2023)

Tumor Prevalence Dose Effects Model

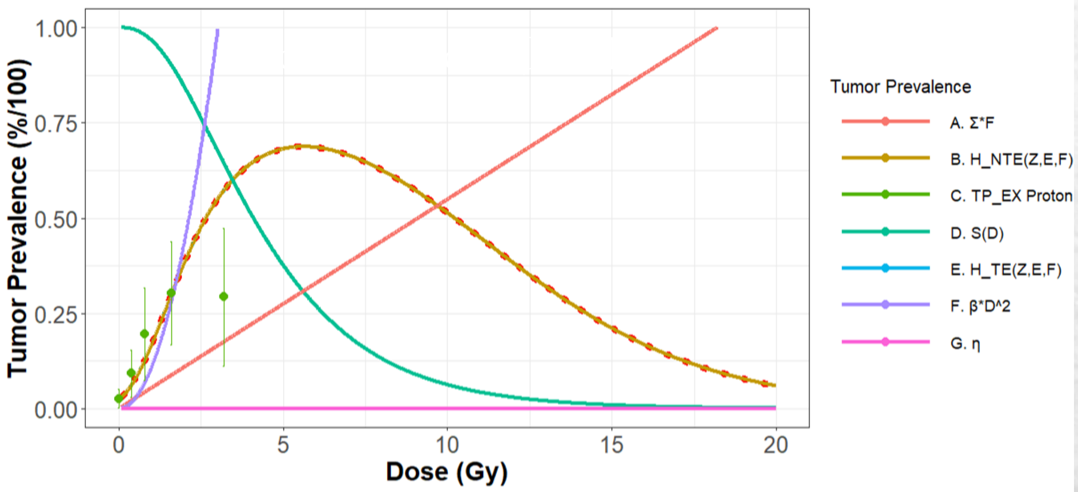
$$TP = 1 - e^{(-H(Z,E,F))}$$

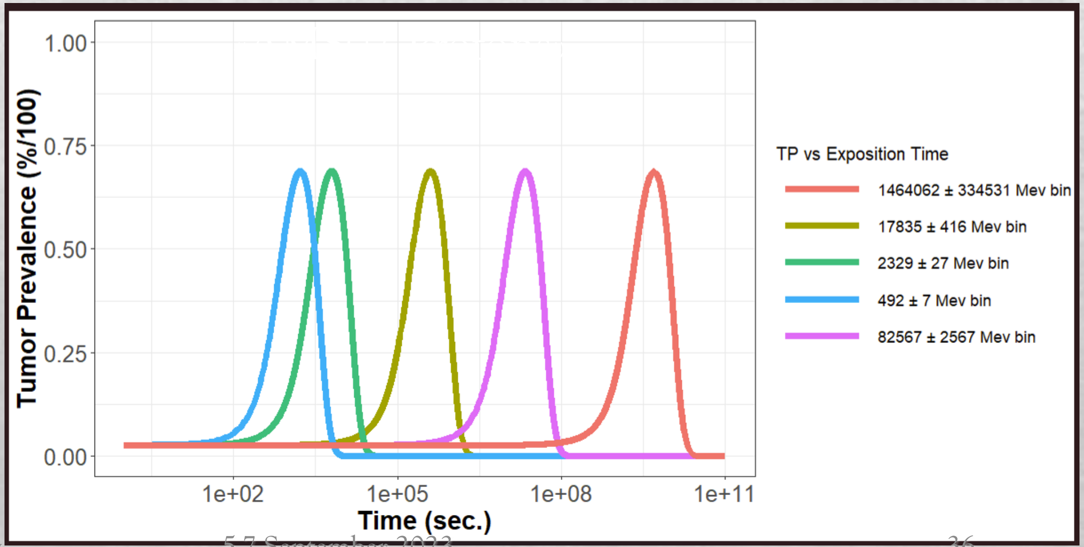
Hazard Function for Target effects

$$H_{TE}(Z,E,F) = H_0 + [\Sigma F + \beta_{CP} D^2] S(Z,E,F) .$$

Hazard Function for Target + Non Target Effects

$$H_{NTE}(Z,E,F) = H_0 + [\Sigma F + \beta_{CP} D^2 + \eta] S(Z,E,F)$$





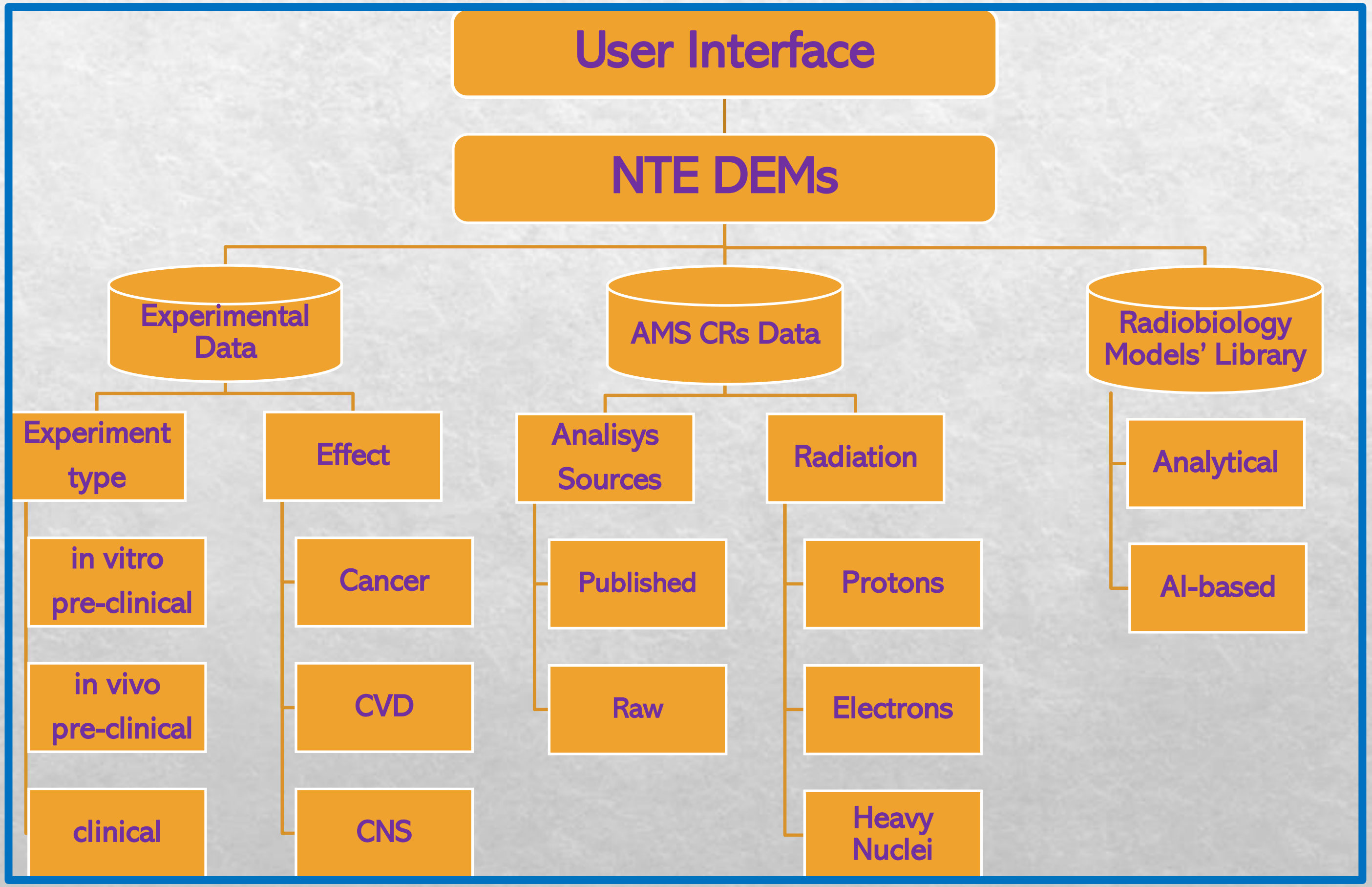
The future evolution of the NTE-DEM software

Internal Note (May 2023)

The future evolution of the NTE-DEM software architecture will incorporate advancements to further understand the effects of space radiation exposure.

By utilizing the AMS-02 detector, we will continue to measure and analyze various components of Cosmic Rays (CRs), including electrons and heavy nuclei.

Our ongoing software development aims to enhance the NTE-DEM software architecture by integrating the Radiobiology Mathematical Models' Library, which specifically addresses the biological mechanisms of Non-Targeted Effects (NTE). Additionally, we will leverage AI-based data analysis techniques for more robust and insightful results.



PSO POLICY STUDIES ORGANIZATION

The international association for decision makers

Advancing Space Radiobiology through interdisciplinary research: Insights from the INFN Roma Sapienza AMS Group

10:10 AM – 11:20 AM at Room 1

Alessandro Bartoloni
INFN Roma & CERN
Speaker's Page

Other speakers: TBA

Read more information about this panel

PSO ask me to organize a 1h panel with multiple speakers on the topic

21 – September – 2023
10:10 -11:20 AM – EDT

Please Join !

And let me know if you want participate as speaker

REV1: A fully automated & reusable space vehicle for in-orbit manufacturing & testing

- High & versatile on-board volume capacity
- Automated and astronaut-free
- Reusable vehicle
- Short & reliable Time-to-Space
- Service-focused business model

Background: ESA ScaleUp

- **July 2023**: Space Cargo Unlimited passed Step 1 of the **ESA ScaleUp INVEST** application and gaining the label "**supported by ScaleUp**", and joining the **ScaleUp Marketplace**

- **On-going:** Space Cargo Unlimited is in the position to propose **up to 5 deals** to ESA and benefit of the **monetary support** – up to **80% of the contract value** –

- *Space Cargo Unlimited is developing the first European space-based capacity to enable substantial in-orbit production at benefits of terrestrial needs*

«In orbit Reentry Vehicle (REV1) production-Day»

How : On-line – No Fee
When : 6-11/ November – 2h at 16h CET

REV1 - presentation
(Thales Alenia Space+Space Cargo Unlimited)
V. La Regina

Science Driven Needs -
A. Bartoloni

Conclusions

Technological advancements hold the potential to fulfill the vision of human space exploration, with missions to the Moon and Mars featuring prominently on the agendas of space agencies.

In recent years, notable progress has been achieved in estimating the absorbed dose-effect relationship, enabling better prediction of health risks associated with space exploration.

However, it is important to acknowledge that the available data for modeling radiobiological effects in space remains limited. Conducting experiments on Earth can provide valuable insights into both cancer and non-cancer radiation-induced effects, further enhancing our understanding in this area.

The AMS Roma Sapienza group, as part of the scientific community, is actively engaged in investigating this critical research topic, with a primary focus on utilizing AMS detector data for the advancement of safe human space exploration.

Ongoing research is currently evaluating the Non-Target Effects in Carcinogenesis Risk, representing a significant avenue for further exploration in this field.

Thanks for yours attention !

Alessandro Bartoloni

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AMS02 INFN ROMA and
Sapienza University Web Site

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